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RESISTANCE OF SOLANUM SPECIES TO POTATO VIRUSES A, X, AND Y

R. E. Webb and E. S. Schultz[1]

An extensive preliminary evaluation of the tuber-bearing *Solanum* species contained in the Inter-regional Potato Introduction collection (1) at Sturgeon Bay, Wisconsin, indicated that selections of some species possessed resistance to some major potato diseases (7). Other workers (1, 2, 3, 4) report resistance to various diseases among selections of these species though not specifically in the selections reported here. A number of the selections resistance to infection by potato viruses A, X, or Y in preliminary trials were obtained for more detailed tests. One hundred thirty-eight selections of 31 species and 26 species hybrids were included in these studies. Since most of the selections responded to virus infection essentially as did those previously reported (3, 7), the reactions of only certain selections of the species and species hybrids are reported.

Materials and Methods

Selections of the tuber-bearing species used in these studies were supplied from the Inter-regional Potato Introduction Station, Sturgeon Bay, Wisconsin. These included *S. acaule* Bitt., *S. cardiophyllum* Lindl., *S. chacoense* Bitt., *S. demissum* Lindl., *S. hougasii* Correll, *S. jamesii* Torr., *S. maglia* Schlechtd., *S. phureja* Juz. et Buk., *S. sucrense* Hawkes, *S. stoloniferum* Schlechtd., *S. tuberosum* L. (*S. andigenum*) Juz. et Buk.

The virus inocula for these tests were from cultures maintained in the Schultz potato virus collection (5). Virus A was carried in potato seedling 41956, a virulent strain of virus X in variety Chippewa, and a common strain of virus Y in potato seedling 42898. Inocula for mechanical transfer of viruses A, X, and Y were prepared by grinding infected leaf tissue in a 0.5M solution of a phosphate buffer (pH7) and applying the inoculum with a sterilized gauze pad to plants lightly dusted with Carborundum. Separate gauze pads were used to inoculate plants of each selection to prevent the transfer of latent or unidentified viruses. The inarch-graft technique (6), with a vial of water used to irrigate the infected scion, was used in all graft inoculations.

Each selection was evaluated for resistance to virus infection by mechanical inoculation and by inarch grafting in groups of 5 and 3 plants, respectively. Plant symptoms and/or subinoculations from inoculated plants to the appropriate indicator host were used as criteria for evaluating susceptibility or resistance of selections to virus infection. Th diagnostic hosts used were *S. demissum L.* PI 175404 for virus A, *Gomphrena globosa L.* and *Datura stramonium L.* for virus X, and *Nicotiana tabacum L.* var. Samsun for virus Y.

[1]Accepted for publication September 19, 1960.

[2]Plant Pathologist and Collaborator, respectively, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, Beltsville, Md.

All individuals of certain selections did not respond similarly to inoculation, as previously reported. This was attributed to inadvertent mixtures in the tuber lots or plants during transplanting virous rather than to variation in virus strains.

Results and Discussion

Resistance of Solanum tuberosum (S. andigenum) to viruses A and X. Preliminary evaluations of certain selections of *S. tuberosum* (*S. andigenum*) indicated that some were highly resistant to mechanical inoculation with virus A or X and some showed resistance to virus Y and leafroll virus (*7*). A number of the selections apparently possessed multiple resistance to these viruses. In 1959, 86 selections of *S. tuberosum* (*S. andigenum*) were obtained for a more thorough study of their resistance to mechanical and graft inoculation with viruses A and X and to mechanical inoculation with virus Y. Forty-three of the selections were highly resistant to virus A, 21 were highly resistant to virus X, and 9 were highly resistant to both viruses A and X (Table 1). Of the 43 selections resistant to

Table 1.—*Reaction of clones of Solanum tuberosum (S. andigenum) to inoculation with some potato viruses.*

PI No.	Virus A	Virus X	Virus Y	PI No.	Virus A	Virus X	Virus Y	PI No.	Virus A	Virus X	Virus Y
161401.3	+	+	+	214429	—[1]	+	+	233988.2	—[2]	+	+
161677.1	+	+	+	214431	—[1]	+	+	233989.2	+	—[1]	+
161695.1	—[1]	+	+	214433	—[1]	+	+	233990.1	—[1]	+	+
161698.3	+	+	+	214435	—[1]	+	+	233992	+	+	+
186177.4	+	+	+	214437	+	+	+	233993.1	—[2]	+	+
186180.1	—[2]	—[2]	+	214440	—[2]	+	+	233994.1	+	+	+
193669	+	—[2]	+	217448	+	—[1]	+	233995.1	+	—[2]	+
194121	+	+	+	225628.3	—[2]	+	+	233996.1	+	—[2]	+
194122	+	+	+	230457.5	—[1]	—[2]	+	233997.1	—[2]	+	+
195211	+	+	+	230472.1	—[2]	—[1]	+	233998.2	+	+	+
197932	+	—[2]	+	230496.4	—[2]	+	+	233999.2	—[2]	+	+
197933.2	—[2]	+	+	230497.1	+	+	+	234000	+	+	+
204341	+	—[2]	+	230498.1	—[2]	+	+	234001	+	+	+
205385.1	—[1]	+	+	230499.1	—[2]	—[1]	+	234002.2	—[1]	+	+
205388.1	+	—[1]	+	230500.3	+	+	+	234585.5	—[2]	+	+
205392.1	—[2]	—[1]	+	230503.7	—[2]	+	+	243342	+	+	+
205393.1	—[1]	+	+	232036	+	+	+	243381	+	+	+
205396.1	+	+	+	232041	—[2]	+	+	243382	+	+	+
205622.1	+	—[2]	+	232044	—[2]	—[2]	+	243383.4	—[2]	+	+
205624	+	—[1]	+	232045	+	+	+	243390.6	—[2]	+	+
209417	+		+	232047	+		+	243396.4	—[1]	+	+
209428	+	+	+	232057	—[2]	—[2]	+	243400.4	—[2]	+	+
209432		—[1]	+	232062	+	+	+	243401.3	+	+	+
214421	—[2]	+	+	233981	+	+	+	243484.2	+	+	+
214422		+	+	233982	—[2]	—[2]	+	243436.5	—[2]	+	+
214423	—[1]	+	+	233983.2	—[2]	+	+	243440.3	+	—[2]	+
214424	—[1]	+	+	233984.2	—[2]	+	+	243450.3	—[2]	—[2]	+
214425	—[1]	+	+	233985	—[1]	+	+	243453.3	—[2]	+	+
214426	+	+	+	233987	+	+	+				

[1] = resistant to mechanical, susceptible to graft inoculation
[2] = resistant to graft inoculation
+ = susceptible to mechanical inoculation
PI No. = plant introduction number

viruses A, 15 were resistant to mechanical inoculation but were susceptible to graft inoculation, and 28 were resistant to graft inoculation. Eight selections were resistant to mechanical inoculation with virus Y but were susceptible to graft inoculation, and 13 selections were resistant to graft inoculation. Five selections were resistant to graft inoculation with both viruses A and X. Several selections showed some resistance to mechanical inoculation with virus Y; however, successive inoculations produced infection in most plants of all selections.

Resistance of Solanum species and species hybrids to graft inoculation with virus X. In addition to the selections of *S. tuberosum* (*S. andigenum*), selections of *S. acaule, S. maglia, S. sucrense,* an unidentified selection, and 2 species hybrids that proved highly resistant to mechanical inoculations were graft-inoculated with a virulent strain of virus X (Table 2). Four selections of *S. acaule,* 5 of *S. tuberosum* (*S. andigenum*), and 1 species hybrid failed to react to inoculation during the test period nor could virus be recovered from them. All other selections developed slight to moderate necrotic spotting in the young leaves or necrosis in the growing points. Subinoculations to *globosa* and *D. stramonium,* from the inocu-

TABLE 2.—*Reaction of some resistant Solanum species and species hybrids to graft inoculation with virus X.*

Species and PI No.		Clonal reaction	Reaction of indexing host	
			Gomphrena globosa[1]	*Datura stramonium*[1]
S. acaule	208856	none	—	
S. acaule	208874	none	—	—
S. acaule	210029.1	none	—	—
S. acaule	217450.2	none	—	—
S. maglia	208563	leaf necrosis	—	+
S. sucrense	230465.6	top necrosis	—	—
S. tuberosum	197932	leaf necrosis	—	—
S. tuberosum	186180	top necrosis	—	—
S. tuberosum	205388.1	leaf necrosis	—	+
S. tuberosum	205392.1	leaf necrosis	+	+
S. tuberosum	205622.1	leaf necrosis	—	—
S. tuberosum	205624.1	leaf necrosis	+	+
S. tuberosum	217448	top necrosis	—	+
S. tuberosum	230457.5	top necrosis	—	—
S. tuberosum	230472.1	top necrosis	+	+
S. tuberosum	230499.1	top necrosis	+	+
S. tuberosum	232044	top necrosis	—	—
S. tuberosum	232057	none	—	—
S. tuberosum	233982.2	top necrosis	—	—
S. tuberosum	233989.2	leaf necrosis	—	+
S. tuberosum	233995.1	none	—	—
S. tuberosum	233996.1	none	—	—
S. tuberosum	243440.3	none	—	—
S. tuberosum	243450.3	none	—	—
Unidentified	209771	leaf necrosis	+	+
Species hybrid	210063	leaf necrosis	+	+
Species hybrid	230659	none	—	—

[1] + = infected
— = not infected
PI No. = plant introduction number

lated plants of each selection 35 days after grafting, indicated that the virus was not present or was in very low concentration in the grafted selections. Virus X was detected in 10 selections upon subinoculations to *D. stramonium* but in only 6 selections in parallel subinoculations to *G. globosa.* Plants of *G. globosa* giving a positive reaction upon subinoculation from the grafted plants developed only 1 - 5 lesions on the 4 inoculated leaves, an indication that the virus was in very low concentration in each of the selections that gave a positive reaction on *D. stramonium.*

Resistance of Solanum species and species hybrids to virus Y. Twenty-three selections of 8 species and 2 species hybrids with reported resistance to virus Y were evaluated for resistance to this virus by mechanical and graft inoculation (Table 3). All the selections appeared immune, when mechanically inoculated. Two selections of *S. chacoense,* one of *S. demissum,* one of *S. hougasii,* one of *S. jamesii,* and 5 of *S. stoloniferum* were highly resistant to graft inoculation with virus Y. Of these, the selection of *S. jamesii,* 1 of *S. hougasii,* and 4 of *S. stoloniferum* failed to react to graft inoculation. All other selections developed slight to moderated necrotic spotting in the young leaves and/or necrosis in the growing

TABLE 3.—*Reaction of some Solanum species to inoculation with potato virus Y.*[1]

Species and PI No.[2]		Clonal reaction to graft inoculation	
		Symptoms	Infection[3]
S cardiophyllum	160370	leaf necrosis	+
S. chacoense	133618	leaf necrosis	—
S. chacoense	133663	none	+
S. chacoense	133708	leaf necrosis	—
S. chacoense	175401.1	leaf necrosis	+
S. demissum	160226.5	leaf necrosis	—
S. demissum	160229.4	leaf necrosis	+
S. demissum	160230.4	leaf necrosis	+
S. hougasii	161726.2	leaf necrosis	+
S. hougasii	161740.4	none	—
S. jamesii	195190	none	+
S. phureja	225685.1	leaf necrosis	+
S. stoloniferum	160224	top necrosis	+
S. stoloniferum	161124.2	top necrosis	+
S. stoloniferum	161158.9	none	—
S. stoloniferum	161160.2	none	—
S. stoloniferum	161170.2	none	—
S. stoloniferum	161364.4	none	—
S. stoloniferum	186557.6	leaf necrosis	—
S. stoloniferum	230477.1	leaf necrosis	+
S. tuberosum	205385.1	top necrosis	+
Species hybrid	222947	top necrosis	+
Species hybrid	222952	top necrosis	+

[1]Following mechanical inoculation, no symptoms developed or could virus be recovered in any case.
[2] Plant introduction number.
[3]Indexing host *N. tabacum* var. samsun.
+ = infected
— = not infected

points. Virus Y could not be recovered from some selections that developed symptoms.

Resistance of Solanum species and species hybrids to virus A.

Twenty-four selections of 6 species and 8 species hybrids that had proved resistant to virus A by mechanical inoculation were graft-inoculated with the virus. All the selections proved highly resistant to graft inoculation with virus A (Table 4); although virus A was not recovered from any of the inoculated plants, almost half of them developed symptoms.

TABLE 4.—*Reaction of Solanum species and species hybrids to graft inoculation with potato virus A.*

Species and PI No.		Selection reaction to graft inoculation	Reaction of virus A indicator host PI 175404[1]
S. chacoense	133618	top necrosis	—
S. chacoense	133619	none	—
S. chacoense	133656	top necrosis	—
S. chacoense	133663	none	—
S. chacoense	189219.8	none	—
S. demissum	161149.3	top necrosis	—
S. hougasii	161726.2	none	—
S. hougasii	161740.4	none	—
S. maglia	208563	top necrosis	—
S. phureja	205561.1	none	—
S. phureja	225696.1	leaf necrosis	—
S. phureja	225697.1	leaf necrosis	—
S. stoloniferum	161158.9	none	—
S. stoloniferum	161160.2	none	—
S. stoloniferum	230477.1	none	—
S. species	209771	top necrosis	—
S. species hybrids	210062	top necrosis	—
S. species hybrids	210063	none	—
S. species hybrids	222943	top necrosis	—
S. species hybrids	222945	top necrosis	—
S. species hybrids	222947	none	—
S. species hybrids	222948	top necrosis	—
S. species hybrids	222950	none	—
S. species hybrids	230662	none	—

[1] = infection
PI No. = plant introduction number

Multiple resistance of Solanum species and species hybrids to potato viruses.

Tables 1 and 5 summarize the reactions of the selections to viruses A, X, and Y. Nine selections of *S. tuberosum* (*S. andigenum*), one of *S. maglia*, and 2 species hybrids were resistant to both viruses A and X. Two selections of *S. chacoense*, 2 of *S. hougasii*, 3 of *S. stoloniferum*, and one species hybrid were resistant to virus A and virus Y. No selection proved highly resistant to all 3 viruses.

SUMMARY

Some selections of *S. tuberosum* (*S. andigenum*) were found to possess a high level of resistance to mechanical and graft inoculation with

TABLE 5.—*Solanum species with apparent multiple disease resistance.*

Species and PI No.		Reaction to Virus A	Virus X	Virus Y
S. chacoense	133618	R	S	R
S. chacoense	133663	R	S	R
S. hougasii	161726.2	R	S	R
S. hougasii	161740.4	R	S	R
S. maglia	208563	R	R	S
S. stoloniferum	161158.9	R	S	R
S. stoloniferum	161160.2	R	S	R
S. stoloniferum	161477.1	R	S	R
Species hybrids	209771	R	R	S
Species hybrids	210063	R	R	S
Species hybrids	222947	R	S	R

R = resistant; S = susceptible
PI No. = plant introduction number

viruses A and X. Nine of the selections proved highly resistant to inoculation with both viruses; graft inoculated plants developed no symptoms nor could either virus be recovered from them. Apparent immunity to graft inoculation with virus X was found in selections of *S. acaule, S. sucrense* and 1 species hybrid. Four selections of *S. tuberosum* and 1 selection of *S. maglia* developed symptoms of virus X infection but were poor hosts for the virus as indicated by low titer upon subinoculating to indicator hosts. One selection of *S. cardiophyllum*, 4 of *S. chacoense*, 3 of *S. demissum*, 2 of *S. hougasii*, 1 of *S. phureja*, 1 of *S. tuberosum*, 8 of *S. stoloniferum* and 2 species hybrids were apparently immune from mechanical inoculation with virus Y. Nine of these selections were apparently immune from graft inoculation with virus Y. Apparent immunity to graft inoculation with virus A was found in selections of *S. chacoense, S. demissum, S. hougasii, S. maglia, S. phureja, S. stoloniferum* and 8 species hybrids. About half of the selections developed symptoms of virus A infection but the virus could not be recovered from them. No selection was found to be highly resistant to all three viruses.

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CRIMSON CLOVER, A NEW HOST FOR POTATO VIRUS X[1]

C. B. WILLIS AND R. H. LARSON[2]

The susceptibility of members of the family Leguminosae to potato virus F has been described by Kollmer (4). Two species, *Trifolium incarnatum* L. and *Trifolium subterraneum* L., were found to be systemically infected by several isolates of the virus which were recovered from inoculated plants after 6 months. During these studies, *T. incarnatum* was suspected of being susceptible to potato virus X.

A review of the literature indicated that potato virus X is known to infect systemically only a small number of plant species outside of the family Solanaceae, i.e. 4 members of the Labiatae, 1 member of the Polygonaceae, and 4 members of the Scrophulariaceae (Table 1). The purpose of this study was to determine the extent of systemic infection by potato virus X in certain members of the Leguminosae. A preliminary report on this problem has been presented (6).

TABLE 1.—*Systemic nonsolanaceous hosts of potato virus X.*

Family	Botanical name	Common name	Citation
Labiatae (Mint)	*Lamium hybridum*, Vill.	Henbit	Clinch (1)
	Ocimum basicilum, L.	Basil	Ladeburg *et al.* (5)
	Salvia reflexa, Hornem.		Ladeburg *et al.* (5)
	Satureja hortensis, L.	Summer Savory	Ladeburg *et al.* (5)
Polygonaceae (Buckwheat)	*Fogopyrum esculentum*, Moench	Buckwheat	Hollings (3)
Scrophulariaceae (Figwort)	*Cymbalaria muralis*, Gaertn., Mey. & Scherb.	Kenilworth-Ivy	Ladeburg *et al.* (5)
	Linaria bipartita, Willd.		Ladeburg *et al.* (5)
	L. maroccana, Hook. f.		Ladeburg *et al.* (5)
	L. vulgaris, Mill.	Butter-and-eggs	Ladeburg *et al.* (5)

MATERIALS AND METHODS

For use in this study, stock cultures of 2 previously described strains (2,5) and a field isolate from Green Mountain potatoes were maintained in *Nicotiana glutinosa* L. Leguminous seeds were germinated in vermiculite at about 24°C. and the young seedlings transplanted 3 to a 3-in. pot containing a 3:1:1 mixture of compost, sand, and muck; they were then held at about 20°C. In the mechanical inoculations, raw sap extracted with a mortar and pestle from young recently infected plants of *N.*

[1]Accepted for publication September 21, 1960.

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glutinosa was applied with a glass spatula to the leaf surfaces of young plants. Tap water was applied to the control plants. White Carborundum (600 mesh) was used as an abrasive. The leaves were rinsed with a fine spray of water immediately after inoculation. Inoculated and control plants were held at approximately 20°C.

In each series not less than 18 plants of each species or variety to be tested were inoculated with each of the 2 virus strains and the Green Mountain isolate. All inoculated plants were cut back 2 weeks after inoculation and reinoculated when sufficient new growth had appeared. Two weeks after reinoculation the plants were again cut back and the new growth tested 4 weeks later for the presence of virus.

Tests for the presence of potato virus X were made by subinoculations (with crude juice) to *Gomphrena globosa* L. When the presence of potato virus X was established, subinoculations were then made to *Nicotiana rustica* L. for identification of the strain or isolate present.

TABLE 2.—*Leguminosae tested for susceptibility to the ringspot and yellow strains of potato virus X.*

Common name	Botanical name	Variety	Susceptibility to potato virus X
Alfalfa	*Medicago sativa*, L.	California Common	—
		Cossack	—
		Grimm	—
		Idaho Common	—
		Ranger	—
		Vernal	—
		Washington Common	—
White Sweetclover	*Melilotus alba*, Desr.		—
Yellow Sweetclover	*M. officinalis*, Lam.		—
Kura Clover	*Trifolium ambiguum*, M.B.		—
Strawberry Clover	*T. fragiferum*, L.	Palestine	—
		Salina	—
Cluster Clover	*T. glomeratum*, L.		—
Alsike Clover	*T. hybridum*, L.		—
Crimson Clover	*T. incarnatum*, L.	Chief	+
		Dixie	+
Red Clover	*T. pratense*, L.	Dollard	—
		Kenland	—
		Lakeland	—
White Clover	*T. repens*, L.	Ladino	—
		White Dutch	—
Subterranean Clover	*T. subterraneum*, L.	Mt. Barker	—
		Nagella	—
		Talarook	—

Results

The Leguminosae tested for susceptibility to potato virus X included 3 genera and 11 species (Table 2). In some instances several varieties of a given species were tested. As indicated, the Chief and Dixie varieties of Crimson Clover *Trifolium incarnatum* L. were susceptible to both the ringspot and yellow strains of potato virus X and carried the virus in high concentration.

All virus recovery attempts from Crimson Clover to both *G. globosa* and *N. rustica* after 4 months were successful. The reactions obtained on *N. rustica* indicated that both strains remained unchanged. Neither the ringspot nor the yellow strain were recovered following inoculation of any of the other members of the family Leguminosae listed in Table 2.

The Chief and Dixie varieties of Crimson Clover also proved susceptible to the field isolate of potato virus X. The field isolate was not used in the inoculation series involving the other Leguminosae listed in Table 2.

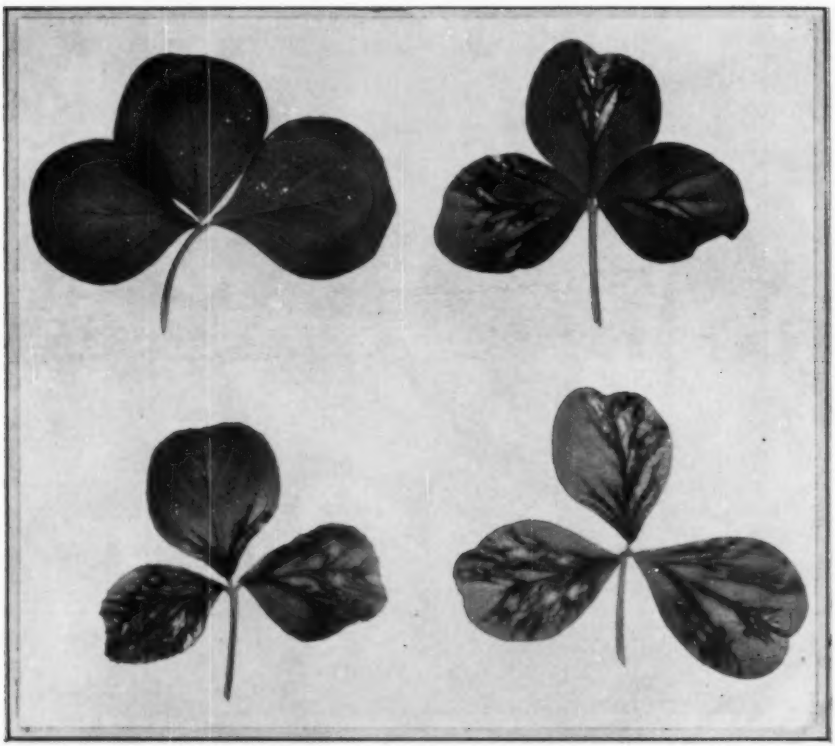

FIG. 1.—Symptoms of systemic infection by potato virus X (ringspot strain) in *Trifolium incarnatum* var. Chief after 7 weeks. Left upper leaf is from comparable control plant.

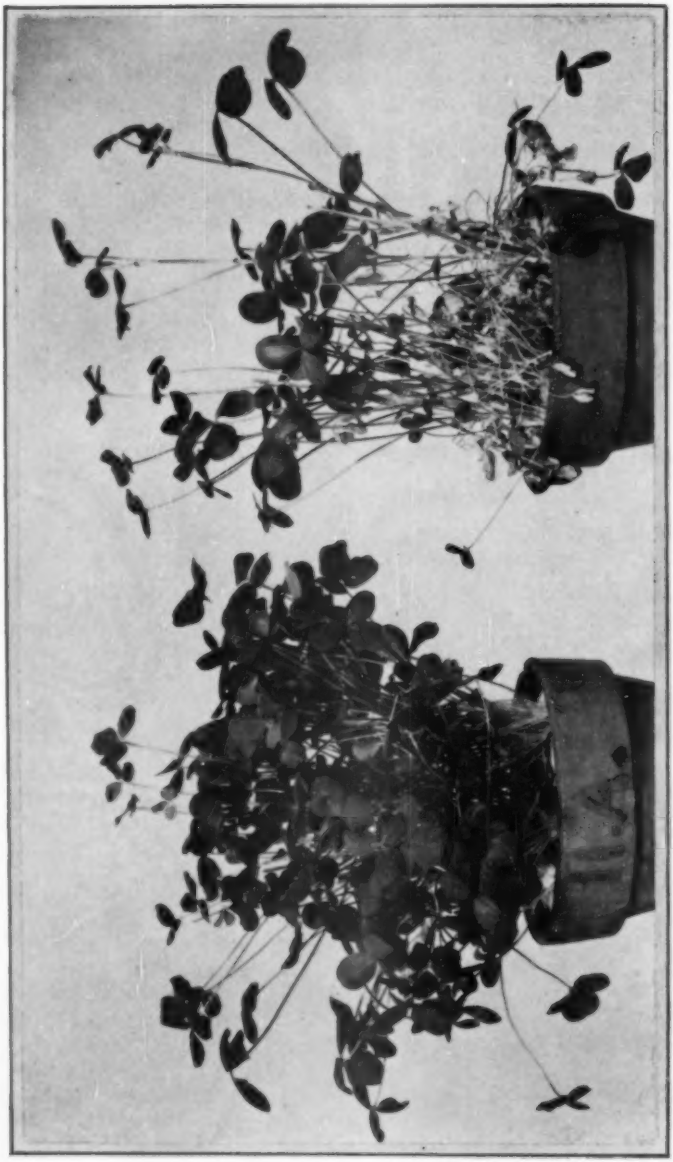

FIG. 2.—*Trifolium incarnatum* var. Chief. Right: Plants infected with the ringspot strain of potato virus X after 4 months. Left: Comparable control plants.

Primary symptoms of infection by either the ringspot or the yellow strain appeared on the inoculated leaves of both varieties of Crimson Clover after 12 to 14 days as a slight interveinal mottle and chlorosis. These initial symptoms were followed by a well-defined veinal necrosis that increased to involve the entire leaf.

The systemic symptoms induced by either strain were evident 4 to 5 weeks after reinoculation, a slight interveinal mottle appeared first; this later intensified to become chlorotic, and a pronounced veinal necrosis became evident as the chlorotic conditions incrased (Figs. 1, 2).

Although no field inoculations have been carried out, it is reasonable to expect that Crimson Clover could play a role in the spread of the potato virus X in potato-growing areas.

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POTATO VARIETY TRIALS (WISCONSIN)

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Red Dot Foods, Inc. grows about 2,500 acres of potatoes on its farms in Wisconsin and Alabama. The potatoes produced supply about 40% of the annual requirements of the various chip factories owned and operated by the company.

This paper is a report of the variety trials in Wisconsin, a later paper will give the results of the tests in Alabama. The varieties grown on most of the Red Dot acreage in Wisconsin are: Early Ohio for the summer crop and Kennebec mostly for the storage crop.

Early Ohio has certain advantages as grown at Waupaca and Rhinelander, Wis. Its tubers are developed early in the season. They usually have relatively high percentages of solids and good quality. Satisfactory chips can be made from them when they are still immature. The disadvantages are that some of the immature tubers have red streaks in the flesh that detract from the color of the chips. Furthermore the variety is susceptible to various diseases, such as late blight, black leg and virus diseases. One of the specific objectives of the research program is to replace the Early Ohio for the early crop in Wisconsin.

Kennebec is the principal variety grown on the Red Dot Farms in Wisconsin for the late or storage crop. It sets its tubers relatively early and usually produces high yields. Its tubers are smooth with shallow eyes. It stores well, if mature, and the chips made from its tubers are usually good to excellent in quality. It is resistant to mild mosaic and late blight. However, it is so late that it rarely matures, at Rhinelander, before the advent of killing frosts and sometimes when stored in an immature state its tubers do not keep satisfactorily. It is susceptible to verticillium wilt resulting in losses in yield of potatoes. Furthermore, the verticillium fungus causes necrosis in the tuber flesh, resulting in a reduction in the yield of chips, and adding to the cost of producing them. It is not so susceptible to verticillium as many other varieties; and in spite of a few handicaps which are counterbalanced to a great extent by its habitual high yields, Kennebec is the best storage variety available at present. Another specific objective of the research program is to breed varieties with the good qualities of Kennebec but which mature earlier and are resistant to verticillium wilt. The results to date look promising.

Since Red Dot grows potatoes under a wide range of conditions; on light soils and on heavy soils; under irrigation and without irrigation; it is improbable that one variety will perform to its full capacity at all locations, or on all the acreage at one location. Therefore the first concern of the Research Program, is to breed a number of varieties, each of which will be superior in yield and chip quality when grown in a particular location, under the conditions of soil and climate peculiar to that place. A wide range of adaptability, therefore, is not so important

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as outstanding yield, dry matter content and chip quality produced in a specific set of environmental conditions.

In the breeding of such varieties many characters are involved. High yield, high dry matter and high chip quality must be combined with early maturity, smooth shape, shallow eyed tubers, good keeping qualities under various temperatures and conditions of ventilation, and high speed of reconditioning after cold storage.

A variety may possess most of these desirable characters and be outstanding under careful methods of growing and handling but under some conditions it may give a mediocre performance. Because of this, tests are made to determine the cultural practices that will give the best results in a specific location. These tests include seed treatments, weed control, and kind, amounts and methods of application of fertilizers. Factors affecting handling, grading, transportation and storage such as maturity, rest period and reactions to various storage temperatures and conditions are studied. The reactions of parents, progenies and varieties to such diseases as verticillium wilt, internal necrosis and common scab and the combining of disease resistance with other characters of economic value constitute an important part of the Red Dot research work.

Materials

The initial breeding stocks used in the investigations consist of varieties and disease-resistant seedlings produced by the National Potato Breeding Program. In addition, new varieties, parent stocks and family lines, especially those reported to have high chip quality and disease resistance are secured from State Experiment Stations and from Canada.

Procedures

Madison, Wisconsin — In the greenhouse, parents that have been selected for high chip quality, superior horticultural characters, and disease resistance are planted and many crosses and selfs made. In each of the last four years an abundance of seed was produced. Approximately 16,000 new seedlings are grown annually. Hundreds of selections from lines bred for resistance to verticillium wilt are tested in the greenhouse for their reactions to this disease.

In the Madison laboratory thousands of samples from the test plots are tested for chip color, specific gravity, reaction to various storage treatments, with special emphasis on capability to recondition after cold storage.

Rhinelander, Wisconsin — On the Research Farm at Rhinelander from 20 to 25 thousand new seedlings are planted annually in an isolated field. This number includes those grown in the greenhouse at Madison and a number of unselected family lines obtained from the Plant Industry Station, Beltsville, Maryland and from potato breeding programs in other states and Canada.

At harvest time about 10% of the new seedlings are selected using as criteria tuber shape, smoothness, depth of eye, color and potential yielding ability. The second year these selections are grown in 10-hill rows. About 25% of them are selected again and two samples of each

sent to Madison where one sample is stored at 50° F., the other at 42° F. After 3 to 4 months the potatoes are removed from storage. Those from the 50° room are chipped immediately, those from 42° are cured 4 weeks at 70° to 80° before chipping. Chip color and specific gravity are determined from all samples.

In succeeding years, seedlings that show superior chipping qualities and high specific gravity are tested for yield, vigor, season of maturity, and other horticultural characters. All yield tests are planted in randomized complete blocks with from 4 to 6 replicates. The tests for chip color and specific gravity are repeated. The few that show promise for two to three years are given Red Dot variety numbers and increased for commercial production. As soon as a variety enters commercial production it is evaluated further on the basis of its performance under conditions of mechanized growing, mechanized harvesting and mechanized handling into and from storage in the chip plants.

Seedlings that have been bred for resistance to verticillium wilt are tested for their reactions to this disease in the field. The seed pieces, fresh cut, are dipped in a slurry containing numerous spores of the fungus and planted immediately in warm moist soil. A severe epidemic usually results. Data on vine infection are taken several times during the growing season and at harvest time. Tubers of many seedling varieties are stored. After about 4 months in storage the tubers are examined for necrosis in the flesh caused by the fungus. Promising results that will be reported in a later paper are being obtained.

Many seedling varieties with scab resistant ancestors are planted in a plot of land infested with the fungus to study their reaction to common scab.

Several tests for resistance to late blight have been attempted but the conditions under which the trials were conducted were not conductive to the development of an epidemic and the results up to the present time are negligible. However, the tests are being continued using improved techniques.

Fertilizer tests with various varieties and various treatments are an important part of the research program. The effects of all treatments on yield, percentage solids and chip color are obtained. The results on particular fields and in certain seasons frequently do not agree with the general recommendations. The research findings are given to the Red Dot commercial operators for their use.

Results

Rhinelander, Wisconsin

Early and Medium Early Varieties 1958

In 1958, 13 numbered varieties were compared with Early Ohio and 5 other named varieties. Each variety was planted in 6 randomized blocks, 20-hills per row, plants one foot apart in the rows with the rows three feet apart. Fertilizer was applied at the rate of 1,000 pounds of 5-20-20 per acre and a sidedressing of ammonium nitrate at the rate of 170 pounds per acre. The plots were planted on May 5 and harvested on August 20. The data for maturity, percentage solids, yield and chip color are given in Table 1.

TABLE 1.—*Potato variety tests. Rhinelander, Wisconsin 1958. Early and medium early varieties.*

Variety	Maturity[1]	Solids pct.	Yield per acre over 2" cwt.	Chip[2] color index[4]	Chip[3] color index[4]
Cobbler	E	16.7	156	87	86
Early Ohio	E	16.8	148	89	87
Ia. 8140-1	L	16.6	168	87	85
Kennebec	L	16.4	212	87	85
Plymouth	M	15.8	177	87	88
Pungo	L	16.2	210	89	85
Tawa	M	16.2	184	89	88
Red Dot 1	E	16.5	224	89	87
Red Dot 3	L	16.6	168	88	87
Red Dot 4	E	15.4	179	87	86
Red Dot 5	E	15.9	182	90	88
Red Dot 6	E	17.0	179	89	86
Red Dot 7	E	16.8	198	90	88
Red Dot 8	M	15.5	199	89	88
Red Dot 9	E	16.4	151	90	89
B3404-11	E	16.2	160	89	89
B3584-5	E	16.6	164	89	87
B3604-17	M	16.6	189	88	87
B3749-5	E	17.4	152	89	87
LSD 5%		0.8	27		

[1]Maturity: E = early, M = medium, L = late.
[2]Color of chips one week after harvest.
[3]Color of chips six weeks after harvest warm storage.
[4]Chips with a color of 80 or higher are commercially acceptable.

Maturity — Six of the Red Dot numbers and 3 Beltsville numbers were as early as Early Ohio. The others were medium or late.

Solids — The tubers of Early Ohio tested 16.8% solids. None of the other varieties was significantly higher in solids than the check variety but 14 of them were in the same class and 4 were lower in dry matter content.

Yields — Eleven varieties were significantly higher in yield than the check variety and none of them was lower.

Chip color — Chips of excellent color usually can be made from potatoes direct from the harvest field but if the tubers are held for some time in warm storage, it sometimes happens that, the chips produced are too dark in color to be acceptable. Samples of the varieties in the early varietal test were chipped the week following harvest. Other samples of the same varieties were stored in the basement of the chip factory at Madison and chipped about 6 weeks later. Statistically, there were highly significant differences among varieties and between times of chipping, but in spite of the statistics, the color of all chips, whether fried directly after harvest or after 6 weeks in warm storage would be considered excellent from the commercial standpoint. (Table 1)

Rhinelander, Wisconsin
Early and Medium Early Varieties 1959

In 1959, 28 named or numbered varieties of potato were planted in

the early varietal test at Rhinelander. Early Ohio was included as a check. The design and procedures were about the same as those described for the 1958 test. The data for maturity, percentage solids, yield of tubers per acre, yield of dry matter per acre and chip color indexes are given in Table 2.

TABLE 2.—*Potato variety tests — Rhinelander, Wisconsin 1959. Early and medium early varieties.*

Variety	Maturity[1]	Solids pct.	Yield per acre over 2" cwt.	Yield per acre total cwt.	Yield dry matter[2] per acre lbs.	Chip[3] color index[5]	Chip[4] color index[5]
Cobbler	M	20.7	176	208	4306	85	87
Early Ohio	E	19.9	160	193	3841	88	87
Ia. 8140-1	M	20.5	140	165	3383	86	87
Kennebec	L	20.0	177	200	4000	88	86
Norland	E	19.4	204	218	4229	87	89
Tawa	E	20.0	168	188	3760	89	88
Red Dot 1	M	20.2	197	208	4202	89	88
Red Dot 3	M	21.0	177	192	4032	90	89
Red Dot 4	M	19.7	171	185	3645	90	89
Red Dot 5	E	19.6	192	223	4371	87	88
Red Dot 6	E	20.3	184	201	4080	88	87
Red Dot 7	M	20.5	182	195	3998	90	89
Red Dot 8	E	19.1	147	189	3610	89	89
Red Dot 9	E	19.8	131	168	3326	90	90
Red Dot 14	E	21.1	132	157	3313	89	90
Red Dot 15	M	20.4	159	189	3856	89	90
Red Dot 16	E	20.6	135	196	4038	88	88
Red Dot 17	E	20.1	136	151	3035	88	90
Red Dot 18	M	20.7	147	172	3560	85	89
Red Dot 19	M	19.9	191	206	4099	87	89
B3404-11	M	19.4	163	200	3880	90	90
B3584-5	M	19.4	148	173	3356	85	87
B3622-4	E	20.4	135	161	3284	89	89
B3749-5	E	21.1	126	175	3693	89	90
ND 3324-2	E	19.2	155	191	3667	85	85
F 4631	M	19.9	175	186	3701	89	89
Ag 29	M	20.5	206	217	4449	88	88
CS 11889	E	20.2	135	152	3070	86	88
LSD 5%		0.4	20				

[1]Maturity: E = early, M = medium early, L = late.
[2]Calculated by multiplying total yield by percentage solids.
[3]Chipped the week after harvest.
[4]Chipped about 7 to 8 weeks after harvest.
[5]Chips with a color index of 80 or higher are commercially acceptable.

Maturity — On August 10, Early Ohio and 13 other varieties were scored early, Cobbler and 12 others were classed as medium and Kennebec was late in maturity.

Solids — The percentage solids of all varieties were relatively high. The average for Early Ohio was 19.9% solids. Twelve varieties were higher in dry matter than Early Ohio, 5 were lower and the others were in the same class.

Yield — Early Ohio yielded 160 cwt. of potatoes over 2 inches in diameter. The least significant difference between means at the 5% level was 20. With this as a criterion 7 varieties; Norland, Ag 29, and Red Dot numbers 1, 5, 6, 7, and 19 outyielded Early Ohio; 13 others were in the same class and 7 were significantly lower in yield.

Dry matter per acre — The calculated dry matter per acre of Early Ohio was 3841 pounds. Irish Cobbler and 12 others including Kennebec, Norland, Ag 29, B3404-11 and 8 Red Dot varieties were higher in dry matter per acre than Early Ohio.

Chip color — The color of the chips made the week after harvest and again about 7 to 8 weeks later ranged from 85 to 90 with means of 88. It is evident that the chips made from all 28 varieties the week after harvest had excellent color and that 7 to 8 weeks in warm storage had no marked effect on chip color.

Rhinelander, Wisconsin

Late and Medium Late Varieties 1958.

In 1958, 21 varieties were included in the late or medium late trials. The design and procedures were about the same as those described for the early variety test 1958. The plots were planted May 5 and harvested Sept. 15. Two samples of 6 tubers from three replicates were shipped to Madison. One sample of each was stored at 50° and the other at 42°. Percentage solids and chip color were determined for all sampls. Data for yield, solids and color of chips from both storage treatments are given in Table 3.

Yield — Kennebec with a yield of 381 cwt. of potatoes over 2" in diameter outyielded all the other varieties significantly. However, several of the other varieties produced high yields. Eight varieties not including Kennebec, yielded more than 300 cwt. of potatoes over 2 inches in diameter. Among the higher yielding varieties were Red Dot 2 with a yield of 316 cwt. and Red Dot 3 yielding 301 cwt. These 2 varieties were more mature than Kennebec, a character that might compensate for the somewhat lower yields.

Solids — None of the 21 varieties was higher in percentage solids than Kennebec. However, 8 varieties were in the same class.

Chip color 50° — Chips made from the tubers of Kennebec and 11 other varieties scored higher than 80, after storing 3 months at 50° F. and chipping direct from storage.

Chip color 42° — Chips made from the tubers of Kennebec and 13 other varieties scored 80 or higher after the potatoes were stored about 3 months at 42° F. and chipped after 4 weeks curing at 70° to 80°.

Chip color, both storage treatments — The chips made from Cherokee, Delus, Katahdin, Kennebec, Manota, Pungo, Red Dot numbers 2, 11 and 12 and Russet Sebago scored 80 or higher after both storage treatments.

Rhinelander, Wisconsin

Late and Medium Late Varieties 1959

In 1959 the varieties in the late and medium late variety test at Rhinelander were planted in 6 replications. Each plot was planted with

TABLE 3.—*Potato variety tests — Rhinelander, Wisconsin 1958*
Late and medium late varieties.

Variety	Yield over 2" per acre cwt.	Solids[1] pct.	Chip color[2] 50° storage index[4]	Chip color[3] 42° storage index[4]
Cherokee	304	18.7	86	82
Delus	288	19.8	83	83
Ia. 8140-1	284	19.9	79	80
Katahdin	293	18.0	84	80
Kennebec	381	19.5	85	84
Keswick	296	18.7	77	72
Manota	228	17.3	86	81
Marygold	286	18.1	79	77
Mohawk	339	19.5	71	76
Plymouth	292	17.5	79	82
Pungo	319	17.3	81	82
Red Dot 1	210	17.2	84	75
Red Dot 2	316	18.5	84	86
Red Dot 3	301	19.3	78	77
Red Dot 5	231	16.0	85	77
Red Dot 11	202	17.1	85	83
Red Dot 12	244	18.8	86	87
Russet Sebago	312	18.6	86	80
Russet Rural	322	19.4	78	83
Saranac	245	17.1	75	76
B3408-1	302	17.9	78	84
LSD 5%	36	0.8	3.4	3.1

[1]Average for samples stored at 50° and 42°.
[2]Chipped direct from 50° F. storage.
[3]Stored at 42° F. for about 3 months and chipped after 4 weeks curing at 70° to 80°.
[4]Chips with a color index of 80 or higher are commercially acceptable.

25 seed pieces, 12 inches between hills and 36 inches between rows. The data, for 33 varieties, for percentage solids, yield per acre of potatoes, calculated yield of dry matter per acre, and chip color indexes for 3 storage treatments are given in Table 4.

Yields — The standard variety Kennebec was outyielded significantly by Saco and Red Dot 20. Marygold, Mohawk, Plymouth, Pungo and Russet Rural were in the same class as Kennebec. All others were lower in yield than the standard. The production of potatoes over 2" in diameter ranged from 90% to 99% of the total with a mean of 97%.

Dry matter — Saco with a calculated yield of 9467 pounds of dry matter per acre was outstanding. Russet Rural was second with 8517 pounds and Red Dot 20 ranked third with 8096. Kennebec produced 7663 pounds of dry matter per acre.

Chip color before cold storage — Chips made from many varieties of potatoes fried before the tubers are put in cold storage usually score 80 or higher in color. This was true of only 19 of the 33 varieties in this test. The dark color of the chips made from some of the other varieties may be accounted for by the effects of the killing frost that occurred the night before the plots were harvested. On the day the tubers were dug the internal temperature of some of them was 38° F. This,

TABLE 4.—*Potato variety tests. Rhinelander, Wisconsin 1959. Late and medium late varieties.*

Variety	Solids pct.	Yield per acre over 2" cwt.	Yield per acre total cwt.	Yield per acre dry matter[1] lbs.	Chip color[2] index[5]	Chip color[3] index[5]	Chip color[4] index[5]
Blanca	19.9	272	286	5691	80	69	69
Delus	21.8	315	318	6932	81	77	80
Katahdin	18.4	311	319	5870	81	74	76
Kennebec	19.4	389	395	7663	81	82	82
Manota	20.1	284	297	5970	77	74	75
Marygold	18.8	365	371	6975	74	68	70
Mohawk	19.7	363	367	7230	83	73	78
Navajo	20.5	237	263	5392	84	75	75
Plymouth	17.3	363	367	6349	76	74	74
Pungo	18.2	378	383	6971	78	72	75
Red Dot 1	19.0	290	297	5643	78	74	71
Red Dot 2	19.2	283	294	5645	80	80	78
Red Dot 3	19.9	336	344	6846	79	72	71
Red Dot 5	18.2	297	306	5569	79	72	73
Red Dot 8	17.3	316	327	5657	90	89	87
Red Dot 10	18.6	257	276	5134	86	84	81
Red Dot 20	18.4	428	440	8096	78	78	77
Red Dot 27	18.2	262	272	4950	86	80	81
Red Dot 28	18.8	270	278	5226	88	77	75
Russet Sebago	19.9	338	350	6965	85	79	75
Russet Rural	21.4	380	398	8517	76	77	79
Saco	20.1	446	471	9467	81	72	76
B3410-18	18.6	221	231	4297	81	78	74
B3604-17	18.0	306	312	5616	81	79	75
B4090-55	18.4	342	349	6422	78	76	80
B4097-22	19.7	305	315	6206	81	74	75
B4144-4	17.7	239	244	4319	77	78	78
47156	20.7	260	268	5548	78	77	82
CS11888	19.0	247	252	4788	78	71	77
CS11889	19.0	227	232	4408	83	75	73
F5312	20.5	309	320	6560	86	82	80
Ia. 8140-1	20.3	333	343	6963	85	83	82
ND 2774-32	18.0	252	266	4788	78	75	71
LSD 5%	1.1	39			4	5	4

[1]Calculated by multiplying total yield by percentage of solids.
[2]Chipped before storage.
[3]Chipped direct from 50° storage.
[4]Stored at 42° for 9 weeks. Chipped after about 4 weeks curing at 70° to 80°.
[5]Chips with a color index of 80 or higher are commercially acceptable.

perhaps, darkened the color of the chips made from some varieties. However, others did not seem to be affected. Red Dot 8, one of the best parents for transmitting desirable chip color graded 90, nine points higher than Kennebec, a highly significant difference. Chips made from 6 other varieties Red Dot 10, 27, 28 and Russet Sebago, F5312 (a Canadian variety) and Iowa 8140-1 were significantly lighter in color than those made from Kennebec.

Chip color 50° F. — The chips made from Kennebec and 6 other

varieties scored 80 or higher in color when fried upon removal from 9 weeks storage at 50° F. Again the chips of Red Dot 8 with a score of 89 was significantly higher in color than those made from Kennebec. The color from the chips of 3 other Red Dot numbers 2, 10 and 27, and of F5312 and Iowa 8140-1 scored 80 or higher in color. If the least significant difference between means 5, is taken into account colors from 77 to 87 would be in a class with the color of the chips made from Kennebec. These limits would include 14 varieties other than Red Dot 8 and Kennebec.

Chip color 42° F. — Chip color of the 33 varieties stored 9 weeks at 42°, and reconditioned 4 weeks, ranged from 69 for Blanca to 87 for Red Dot 8. The least significant difference between means in this test was 4. On this basis the chips made from Red Dot 8 with a score of 87 were the only ones that were significantly higher in color than those from Kennebec with a score of 82. The chips of 11 other varieties were in the same class for color as the Kennebec chips. The chips of Delus, Kennebec, Red Dot numbers 8, 10 and 27, B4090-55, 47156, F5312 and Iowa 8140-1 scored 80 or higher in color.

Chip color all 3 storage treatments — The varieties, the chip color of which, scored 80 or higher before storage, direct from 50°, and after 9 weeks storage at 42° and curing 4 weeks were: Kennebec, Red Dot 8, 10 and 27, F5312 and Iowa 8140-1.

Summary

Red Dot Foods, Inc. grows on its farms about 40% of the potatoes required by the various chip factories owned and operated by the company. In Wisconsin, Early Ohio is grown for the summer crop and chipped direct from the harvest fields and Kennebec is grown mostly for storage. These varieties have many desirable characters combined with some unwanted traits.

The present objective of the research program is to breed varieties superior to those now commonly grown on the Red Dot Farms in Wisconsin. In Madison the seed of crosses and selfed lines are produced and the seedlings are grown to maturity in the greenhouse. The tubers are planted for increase on the Red Dot Research Farm, Rhinlander. In succeeding years selections are tested for yield, season of maturity, tuber shape, smoothness, solids and chip color under several storage treatments. In 1958 and 1959 a number of early or medium early varieties outyielded Early Ohio and chips with good to excellent color were made from all varieties in the tests when the tubers were chipped direct from the harvest field or after 6 to 8 weeks in warm storage. In 1958 in the late or medium late variety tests Kennebec outyielded the other 20 varieties significantly, but 8 of the others yielded more than 300 cwt. of potatoes over 2 inches in diameter. Eight varieties were in the same class as Kennebec in percentage solids. The chips from Kennebec and 11 other varieties scored higher than 80 in color direct from 3 months storage at 50°. The chips made from 14 varieties scored 80 or higher after storage for 3 months at 42° and curing 4 weeks at 70° to 80°. Commercially acceptable chips were produced from 10 varieties from both temperature treatments. In 1959 Saco and Red Dot 20 outyielded Kennebec. Five other varieties

were in the same yield class as the latter. Saco outyielded all others in calculated yield of dry matter per acre. Russet Rural was second and Red Dot 20 was third. Chips made from tubers of many varieties direct from the harvest field scored 80 or higher in color, but this was true of only 19 of the 33 varieties in the late variety test in 1959. The dark color of the chips of the other 14 varieties was due no doubt to the killing frost that occurred the night before the plots were harvested. Chips made from Kennebec scored 80 in color but chips from 7 other varieties were significantly higher in color than those made from the standard variety. The chips made from 7 varieties scored 80 or higher in color fried direct from 9 weeks storage at 50°. Stored at 42° and cured 4 weeks the chips made from Red Dot 8 with a score of 87 were significantly lighter in color than those made from Kennebec. The chips made from 11 other varieties were in the same class for color as the Kennebec chips. Chips made from 6 varieties scored 80 or higher before storage, direct from 50°, and after 9 weeks in 42° and curing 4 weeks. These were, Kennebec, Red Dot 8, 10 and 27, F5312 and Iowa 8140-1.

ROOTING OF POTATO CUTTINGS[1]

H. W. CHAPMAN AND M. D. CLEGG[2]

The propagation of potatoes from vegetative cuttings has become of increasing importance to plant breeders and other researchers working with this crop. However, very little, if any, information has apparently been published on the subject (2) (4). Yet most persons engaged in research work with potatoes have at one time or another attempted to root cuttings of this crop. If success was achieved results were not published, perhaps due to other more pressing interests of the investigator. An excellent general review of the physiology and morphology of rooting of leafy cuttings is presented by Snyder (6). This paper describes several experiments conducted to determine the best method of rooting potato cuttings.

MATERIALS AND METHODS

Cuttings of several varieties of potatoes were secured from the greenhouse after completion of indexing operations. They were divided into two sets with regard to the tissues involved; apical cuttings from soft tissues including a terminal growing point, and older more completely differentiated tissues from the central portion of a potato stem. These cuttings were usually 4 to 6 inches long and in the latter case contained 3 to 5 leaves. The lowest leaf was removed from the cuttings and the basal ½ inch was dipped into Fermate[3] or Rootone[4] dust as suggested by Murakishi (5). The cuttings were then placed in one of three rooting media; perlite with intermittent misting over the bench and full sunlight, moist sand with shade, or greenhouse potting soil with shade. From time to time the cuttings were inspected for root development. During the summer additional experiments were run, using cuttings from field grown plants.

RESULTS AND DISCUSSION

Some rooting was observed with all treatments, but by far the highest percentage of cuttings rooted and developed the most numerous roots when treated with Rootone and were held in the perlite and mist medium (Table 1). The cuttings rooted equally well whether the basal cut was made at a node or at various locations in the internodal region. Heavy callus development was observed, particularly with the Rootone treatment and profuse root development followed at and above the calloused area (Fig. 1). This result is particularly interesting since Artschwager (1) reported adventitious roots only from nodal regions of the potato. While a definite stimulation of rooting was observed with the Fermate treatment over that of the checks, Fermate with Rootone was no better than Rootone alone.

Sand was also a good medium but waterlogging must be avoided. Thus mist could not be used. Apparently aeration of the basal end of the

[1]Received for publication October 3, 1960. Published with the approval of the director as S.S. paper 642 Colorado Agricultural Experiment Station, Fort Collins, Colorado.
[2]Associate Horticulturist and graduate assistant respectively.

TABLE 1.—*Number of apical cuttings of several potato varieties placed in three different media showing root development after 16 days.*

Treatment and Variety	Media—(20 cuttings total per treatment)		
	Mist - Perlite	Sand - Shade	Soil - Shade
McClure			
Check	18	11	2
Rootone	20	20	3
Fermate	20	16	3
Russet Rural			
Check	15	18	2
Rootone	20	20	2
Fermate	20	19	0
Burbank			
Check	19	16	3
Rootone	20	20	13
Fermate	20	18	0
Dazoc			
Check	19	19	3
Rootone	20	20	8
Fermate	20	19	0
Red Pontiac			
Check	20	15	0
Rootone	20	20	14
Fermate	20	17	4

cutting is extremely important in rooting. This conclusion is substantiated by the observation that only an occasional cutting will root when placed in water or nutrient solution with no aeration as described by McLean(3). Soil was a very poor medium for rooting, perhaps even more so than indicated in Table 1. Many cuttings reported as rooted, had only 1 or 2 roots and weak callous development. Poor survival and vigor of these cuttings was observed following potting.

Aerial tubers frequently developed on cuttings in the rooting bench. Such tubers delayed rooting and decreased the number and vigor of roots formed. When aerial tubers were removed as soon as they became visible, the time required for rooting decreased and the number of roots increased.

Cuttings taken from plants approaching senescence did not root readily. These plants were no longer actively initiating leaves in the shoot apices and in a few cases the leaves were starting to turn light green or yellowish green in color. Apparently, cuttings made from such tissues are no different than cuttings from mature tissues of many kinds of plants in this respect. Cuttings of various lengths from 2 to 12 inches have been rooted with equal success (Table 2). Apparently only a single growing point is required under optimum conditions. However, more consistent rooting and a greater survival rate following potting can probably be expected if cuttings 4 to 6 inches in length are used.

[3]Fermate—ferric dimethyldithiocarbamate.
[4]Rootone—naphthylacetamide 0.10%, 2 methyl-1 naphthylacetic acid 0.05%, and 2 methyl-1 naphthylacetamide 0.02%.

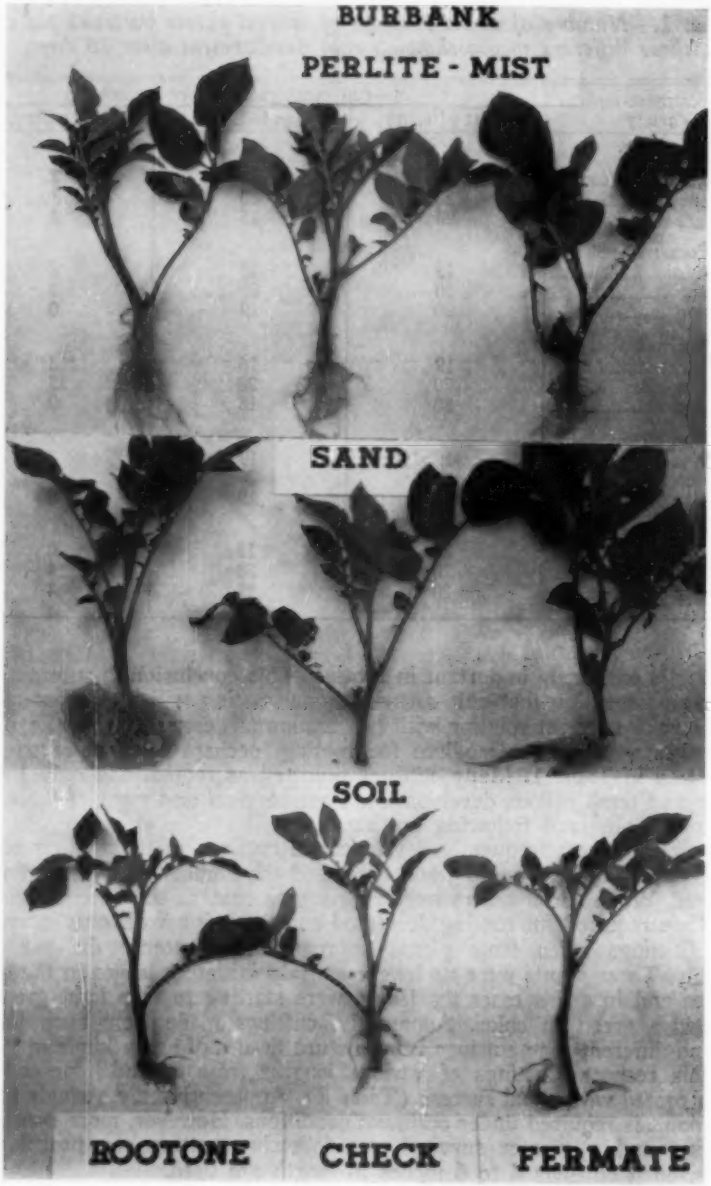

FIG. 1.—Typical rooted cuttings of Burbank variety from three different environments. Rootone or Fermate dusts together with no treatment applied to the cuttings before benching.

TABLE 2.—*Number of cuttings of various lengths rooted after 14 days. Perlite medium with mist and full sunlight.*

Length of cutting	Number rooted	Number not rooted	Number forming tubers
2"	10	0	0
5-6"	10	0	3
10-12"	10	0	1

TABLE 3.—*Rooting response of apical and median cuttings from stems of several varieties of potatoes after 14 days. Perlite medium with mist and full sunlight.*

Variety	20 cuttings total per treatment			
	Apical cuttings		Median cuttings	
	Check	Rootone	Check	Rootone
McClure	18	20	1	20
Russet Rural	15	20	14	20
Burbank	19	20	12	20
Dazoc	19	20	13	20
Red Pontiac	20	20	16	20

A large number of cuttings can be expected to form visible roots within 7 days following benching. However, a greater survival following potting can probably be expected if they are allowed to remain in the rooting bench at least 2 weeks.

Dipping the cuttings in a mild insecticide and fungicide solution before dusting the basal half inch with rooting hormone and benching seemed to be a good practice. Certain groups of cuttings were destroyed by early or late blight fungus while in the rooting bench. Aphid populations may also build up occasionally.

Generally cuttings including a terminal shoot apex will root more quickly and profusely than cuttings from other regions of the potato stem. However, excellent rooting has also been observed from median tissues (Table 3).

CONCLUSIONS

Cuttings from the vines of potato plants will root within 2 to 3 weeks in a perlite medium with intermittent mist and full greenhouse light. Heavy callus and numerous roots can be expected with high survival following potting. Mature tissues, however, should be avoided in selecting material for making cuttings.

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POTATO COMPOSITION AND CHIPPING QUALITY[1]

EDWARD F. HOOVER AND PAUL A. XANDER[2]

INTRODUCTION

In a paper (3) given before this Association at their Fredericton, New Brunswick Meeting in August 1959, we reported that an extensive research program had been initiated by the laboratories of the Wise Potato Chip Company to investigate the relationships between the chemical composition of potato tubers and their chipping quality. In spite of the rather extensive literature available on various phases of this problem, little information was available concerning the interrelationships of a wide variety of known components of the potato tuber with the chipping quality of the potatoes.

Probably the best documented facet of this work is the apparent relationship betwen the occurrence and concentration of the monosaccharide reducing sugars and the browning of potato chips during processing. It has been shown by many investigators that increasing quantities of these compounds in potatoes result in increasingly darker colored potato chips. It was generally believed and has been adequately proven that most of the colored products which form in potato chips during processing do so as a result of the Maillard or browning reaction. This, according to most sources, involves a reaction between carbonyl containing substances such as glucose and fructose and amino compounds, although there is some disagreement regarding the actual role of the latter group of compounds in the reaction.

Although it was generally recognized that reducing sugars represented the most important single group of compounds responsible for the Maillard reaction in potato chip processing, considerable evidence was available suggesting the possible involvement of other types of compounds. The work initially undertaken in this laboratory was designed to provide qualitative and as much as possible semi-quantitative compositional data on a wide variety of known potato components. By comparing these data with the known chipping color of the tubers, it was hoped that some evidence would be found which would provide further correlation between potato composition and chipping quality.

MATERIALS AND METHODS

During the 1958 growing season more than 70 potato samples representing named varieties and numbered seedlings were obtained from the various major potato growing areas of the eastern United States and from hydroponic plots established by the Horticultural Section of this laboratory. These potatoes were analyzed immediately after harvest and again after eight weeks of storage at 70° F. Analyses were made for a wide variety of compounds including total reducing sugars, alcohol-soluble and free

[1]Presented at 44th Annual Meeting, Potato Association of America, Green Lake, Wis., August 31, 1960. Accepted for publication September 30, 1960.

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carbohydrates, free amino acids, globulin and water-soluble proteins, protein-bound amino acids, aromatic and aliphatic organic acids, ascorbic acid, and constituents of noncombustible ash.

Studies in 1959 utilized the analytical techniques employed during the 1958 work, but included additional compositional factors not investigated in the earlier studies. These were phosphate distribution and the determination of the activity levels of specific enzyme systems (invertase and sucrose UDP-transglucosylase) believed to be involved in the synthesis and hydrolysis of sucrose in potatoes and enzyme systems believed to mediate the dormancy period of potatoes (apyrase and acid phosphatase).

Fifty one potato samples from the same fields and hydroponic sources as those included in the 1958 work were examined. As previously, the samples were subjected to compositional analyses at harvest and again after storage for eight weeks at 70° F.

The compositional studies being conducted during the current (1960) growing season are based on the quantitative assay of specific individual and group components of potato tubers which during the 1958 and 1959 screening studies, were found to be correlated, at least inconsistently, with chipping color. These include the major soluble carbohydrates, sucrose, glucose, and fructose, basic amino acids, phenolic compounds, ascorbic acid, mineral components, phosphate and nitrogen distribution. Also being assayed are the enzyme systems of sucrose metabolism included in the 1959 studies and those believed to mediate the dormancy period.

Samples were analyzed at 4 week intervals and were stored at 40° F. and at 70° F. The total period of storage at either of these temperatures was at least 16 weeks.

Because of the more complex nature of the 1960 work and the frequency with which the analyses are repeated, it has been necessary to limit the number of potato samples studied to a maximum of two or three varieties from each of three locations (Florida, Virginia, Pennsylvania).

Results

The results of the 1958 work showed that, in accordance with the published literature (4), potato composition is quite variable within limits and depends largely upon variety, nutrition or fertilization, growing media, irrigation, and other factors. Consistent, direct correlation between specific potato components and the chipping color was found only in the occurrence and relative levels of the monosaccharide reducing sugars, glucose and fructose. Increasingly darker chipping color consistently corresponded to the presence in the potatoes of increased quantities of one or both of these compounds. This was in good agreement with most of the work of other investigators reported in the literature.

In addition to the above, evidence was also obtained during the 1958 studies which indicated possible, however inconsistent, correlation between certain other compositional factors of potatoes and their chipping color. As determined by two-directional paper chromatography, the amino acids, proline and phenylalanine, the basic amino acids lysine, histidine and arginine, and the amide asparagine appeared to be present in higher relative concentrations in potatoes producing darker colored chips. Habib and Brown (2) have previously reported similar correlation between the basic

amino acids and chipping color. Decreases in the apparent relative concentration of a major water-soluble protein component of potatoes as shown by paper electrophoresis in veronal buffer appeared to be associated with increases in chipping color. In addition, potatoes which consistently produced light colored chips seemed to contain relatively higher levels of ascorbic acid than potatoes which produced darker colored chips. It was also observed that among potatoes grown under identical conditions, those having higher levels of zinc, manganese and copper generally produced darker colored chips.

The inconsistent nature of many of the findings during the 1958 work prompted the continuance of the screening studies during the 1959 growing season in order to attempt to confirm the previous observations and to study the possibility of further correlation between potato compositional factors and chipping color which had not been observed in the earlier work.

The results of the 1959 studies were in good agreement with those obtained during the 1958 season in that the compositional factors in which the most consistent correlation with chipping color was found were the monosaccharide reducing sugars glucose and fructose. Again the correlation was such that increasing concentrations of these two compounds resulted in increasingly dark chipping color.

A fair degree of correlation was observed between chipping color and the activity levels of the invertase and sucrose UDP-transglucosylase enzyme systems. The former mediates the hydrolysis of sucrose to glucose and fructose. Increases in the activity of this enzyme appeared to be associated with darker chipping color. (Activity was determined by the increase in reducing power of a solution of sucrose after incubation with the crude enzyme extract prepared from potato tubers.) Conversely, the enzyme sucrose UDP-transglucosylase catalyzes the synthesis of sucrose from fructose and uridine diphosphate glucose. The presence of this enzyme system in potato sprouts was reported by Cardini, Leloir and Chiriboga (1) and its presence in the tubers was confirmed in our laboratory. It was subsequently learned that Schwimmer and Rorem of the Western Regional Research Laboratory, USDA, also had observed this enzyme in potato tubers. The 1959 compositional studies suggested that higher levels or increases in the activity of this enzyme system in tubers were associated with good or improved chipping color.

Indications of possible correlation with chipping color were found in variations in the activity of the enzyme apyrase which is believed to be influential in mediating the dormancy period of potatoes (5).

Evidence of correlation with chipping color was also found in variations in the levels of the trace minerals iron, copper, and zinc in the tubers although nonuniformity in the types of variation observed suggest that the correlation with chipping color in this phase may be indirect.

Variations in the levels of the basic amino acid lysine and of phenolic compounds also provided some evidence of correlation with chipping quality. The levels were found to be higher in potatoes producing darker colored chips.

Contrary to the findings of the 1958 growing season, ascorbic acid levels and the water-soluble protein components gave no evidence of correlation with chipping color in the 1959 investigations.

In Table 1 are summarized the compositional factors for which evidence was found during the 1958 studies suggesting implication of these compounds or groups in the browning of potato chips during processing. It will be noted that only reducing sugars, basic amino acids, and certain trace mineral components gave evidence of correlation during both growing seasons. Data for phenolic compounds and the specific enzyme systems were obtained only in the 1959 studies.

Illustrations of the type data upon which our observations during the 1958 and 1959 growing seasons are based are given in Tables 2, 3, and 4.

In Table 2 the total reducing sugar content of five different samples of tubers of the Delus and Onaway varieties is compared with the chipping color of the tubers. Chipping color grade is measured by visual comparison according to an arbitrary scale in which increasing values represent increasingly darker colors. The maximum value at which a product is considered saleable is grade 5. The variety Delus is one which generally produces acceptably colored chips under normal conditions of storage. Tubers of the Onaway variety consistently produce chips of very dark color and rarely, if ever, condition to produce acceptable chips regardless of storage conditions. The data given in Table 2 clearly illustrate the correlation between reducing sugar levels in tubers and their chipping color.

Further evidence of correlation between reducing sugar concentrations and chipping color is shown in Table 3. Here relative levels of sucrose, glucose and fructose in alcoholic extracts of tuber tissue are compared with chipping color. The reported relative concentration values are based on the density of spots formed by reaction of the sugars with o-aminodiphenyl after separation by paper chromatography. Increasing values indicate increasing concentrations. The results show the effects of glucose and fructose and the relative non-involvement of sucrose in the browning reaction.

Table 4 shows the effect of various levels of copper, manganese and iron in potatoes of the Delus and Onaway varieties on chip color. The varietal pairs shown represent experimental plots at different locations. In nearly all cases, the levels of the three trace elements were lower in the tubers of the Onaway variety which produced the darker colored chips.

From the accumulated data gathered during the 1958 and 1959 investigations, it is apparently evident that a number of compositional factors may, under the proper conditions, influence the chipping color of potato tubers. However, only the carbohydrate fractions, specifically glucose and fructose, provided consistent, direct correlation. These fractions, then were obviously the most important for the control of chipping color during processing.

Since potato composition is the direct result of metabolic processes both in the potato plant before harvest and in the tuber itself after harvest, it follows that control of the proper metabolic processes of the potato could result in a tuber which would possess the desired compositional characteristics for chipping.

Enzyme systems mediate the basic metabolic processes in all living organisms. In view of the general compositional data obtained during the

TABLE 1.—*Compositional factors giving evidence of correlation with chipping color.*

	1958	1959
Monosaccharide reducing sugars (glucose, fructose)	+	+
Neutral amino acids (proline, phenylalanine)	+	
Basic amino acids (arginine, histidine, lysine)	+	+
Amides (asparagine)	+	
Water-soluble proteins	+	
Ascorbic acid	+	
Trace mineral components (iron, copper, zinc, manganese)	+	+
Phenolic compounds		+
Enzyme systems ,invertase, apyrase, sucrose UDP-transglucosylase)		+

TABLE 2.—*Total reducing sugar.*

Variety	Chipping color (Arb. scale)	Total reducing sugar (Fresh weight) Per cent
Delus	3	0.07
	3	0.08
	5	0.14
	4	0.13
	4	0.18
Onaway	10	0.38
	6	0.17
	8	0.29
	7	0.22
	7	0.27

TABLE 3.—*Glucose, fructose, sucrose.*

Variety	Chipping color (Arb. scale)	Relative concentration (Arb. scale)		
		Sucrose	Fructose	Glucose
Delus	3	3	..	..
	3	3	Trace	..
	5	3	1	Trace
	4	3	Trace	..
	4	3	1	Trace
Onaway	10	3	2	3
	6	3	1	1
	8	3	3	2
	7	3	2	2
	7	3	2	2

TABLE 4.—*Relation of mineral components to chip color of Delus and Onaway at 5 locations.*

Variety	Chipping color (Arb. scale)	Concentration (Mg./Kilo. fresh weight)		
		Copper	Manganese	Iron
Delus	3	1.2	0.004	8.2
Onaway	10	0.02	0.004	0.6
Delus	3	5.0	0.26	12.9
Onaway	6	3.6	0.12	9.1
Delus	5	3.2	0.67	10.1
Onaway	8	1.9	0.14	7.7
Delus	4	4.8	0.22	8.7
Onaway	7	1.6	0.25	11.7
Delus	4	4.3	0.12	7.4
Onaway	7	2.7	0.07	6.3

Each pair of varieties is from a different location.

screening studies of the 1958 and 1959 growing seasons, it was concluded that studies of the enzyme systems of potatoes, particularly those involved in the metabolism of these components which had been found to influence the chipping color of potatoes consistently, would be of considerable value in the attainment of the ultimate desirable qualities in potatoes. Data of this type would provide a basis for attempts to control the metabolic processes in potatoes genetically.

It is on this basis and the need of quantitative data relative to those compounds which the screening studies of 1958 and 1959 had indicated to be in some way correlated with chipping color that the 1960 compositional studies have been planned and undertaken. At the time of this presentation, the data collected as a result of these studies during the present growing season are insufficient to suggest any specific conclusions or even trends other than the well established effects of low temperature storage on the accumulation of sugars in potatoes and the influence of monosaccharide reducing sugars on chipping color.

Concurrently with the general compositional studies described above, we have initiated a more detailed study of the enzymatic pathways of sugar metabolism in potato tubers. Using Schwimmer's review of the enzyme systems of the potato (5) and additional data obtained in this and other laboratories, a hypothetical scheme has been proposed for the formation of a number of carbohydrate derivatives known to be present in potatoes and believed to be involved directly or indirectly in the browning of potato chips. The scheme, shown in the accompanying diagram indicates the principal enzyme system involved in the formation of the major product of each reaction.

It will be noted that the proposed pathways are essentially cyclic

in nature. This would appear to be a logical assumption on the basis of other metabolic pathways which are also known to be cyclic. In the proposed system, fructose-6-phosphate, formed as a result of photosynthesis can be dephosphorylated to the free sugar by alkaline phosphatase or converted to glucose-6-phosphate by a hexose isomerase. This in turn can also be dephosphorylated to free glucose by alkaline phosphatase. The free sugars and the phosphorylated derivatives esterified in the 6 position are all capable of involvement in the browning or Maillard reaction. The free sugars can, in turn, be reconverted to the -6-phosphate derivatives by the action of hexokinase enzymes in the presence of ATP. Glucose-6-phosphate can be converted to G-1-P by phosphoglucomutase in which form it is available for starch synthesis or conversion to nucleotide sugars such as uridine diphosphoglucose. Glucose-1-phosphate does not readily undergo browning with amino acids (5) and as such, it apparently is not a major factor in chipping color. One mole each of UDPG and fructose can be united to form one mole of sucrose by means of sucrose UDP-transglucosylase. Sucrose synthesis by this pathway would effectively remove fructose, one of the principal factors in the browning of potato chips. Sucrose synthesis, however, could be blocked by the rephosphorylation of fructose by hexokinase or by hydrolysis of UDPG by nucleotide pyrophosphatase. Further, sucrose which is synthesized can be converted back to free glucose and fructose through hydrolysis by invertase. The free sugars can then re-enter the cycle as shown (Fig. 1).

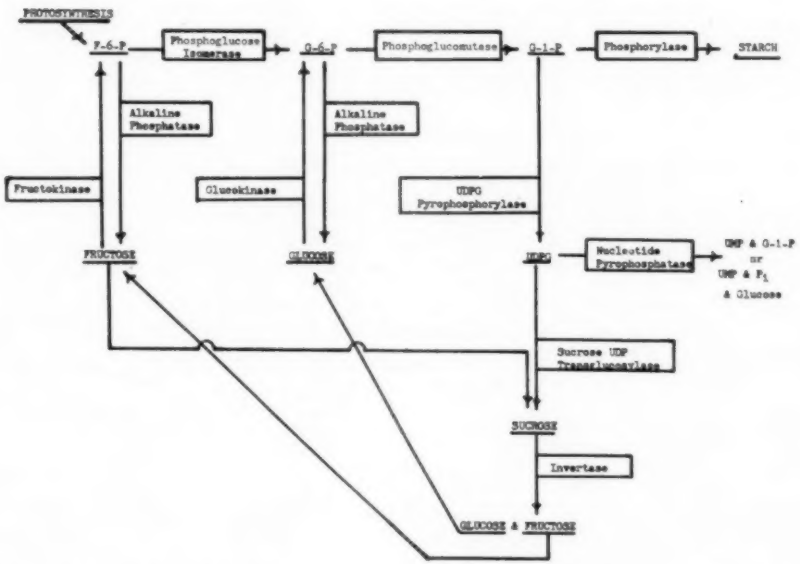

FIG. 1.—Hypothetical scheme for enzymatic transformation of major carbohydrates in the white potato.

All of the enzyme systems included in this hypothetical scheme are known to be present in potatoes. The object of current work in this laboratory is to check the validity of this hypothesis and to obtain data on the presence and relative activities of these enzymes with respect to the chipping color of the tubers from which they are isolated. Cooperative studies leading toward genetic control of specific enzyme systems are being conducted with the Plant Industry Station of the United States Department of Agriculture in Beltsville, Maryland.

Summary

Large scale screening studies conducted during the 1958 and 1959 growing seasons revealed that only reducing sugars gave consistent evidence of correlation with the chipping color of potatoes. However, certain other compositional factors including ascorbic acid, basic amino acids and specific enzyme systems were found to be at least inconsistently correlated with chipping color. More extensive quantitative studies of these factors have been undertaken during the 1960 growing season. Particular attention is being given to the enzymatic pathways of carbohydrate metabolism in the potato and a hypothetical scheme for the synthesis and utilization of glucose, fructose, and sucrose has been proposed.

Acknowledgment

The authors wish to express their gratitude to Edward Hugick and Roderic Moore of our laboratories for their technical assistance and to Dr. Geoffrey Houghland, Dr. August Kehr, Mr. Robert Akeley, and others of the Plant Industry Station, Beltsville, Maryland, and Eastern Regional Research Laboratories, Philadelphia for advice and suggestions relative to the planning and execution of this work.

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NEWS AND REVIEWS

CALL FOR PAPERS

The 45th Annual Meeting of the Potato Association of America will be held at Wenatchee, Washington, July 26-28th, 1961.

Please send titles of papers to be presented at this annual meeting to Richard L. Sawyer, Long Island Vegetable Research Farm, Cornell University, Riverhead, New York, by June 10. Along with the title please include: (a) approximate time required to present your paper, (b) if an illustrated talk, the size of the slides to be used, and (3) the names and official addresses of the authors as you wish them to appear on the program. As has been our custom, we will again distribute mimeographed abstracts of these papers to members attending the annual meeting. These abstracts will be published in the American Potato Journal. Therefore, abstracts should accompany the titles of the papers. Abstracts should not exceed 250 words. Presentation of papers should not exceed 15 minutes, and the use of 2 x 2 slides is preferred.

We would like to receive good papers concerned with problems in potato physiology, breeding, diseases, production, quality, nutrition, storage, transportation, processing and marketing.

Your cooperation in sending the titles and abstracts as early as possible will aid in the mimeographing of these abstracts and the prompt preparation and printing of programs. Titles and abstracts received after our deadline of May 15 may not be accepted. Please bring this notice to the attention of your students and colleagues.

RICHARD L. SAWYER, *Secretary*
Potato Association of America
L. I. Vegetable Research Farm
Riverhead, New York

ACCOMMODATAIONS

The Columbia Hotel, 130 S. Wenatchee Ave., has been chosen as the headquarters for registration and meetings. Room rates are: $5.00-$7.00 single; $7.00-9.00 two people, double; $8.00-$11.00 two people, twin.

Other facilities available include the following:

	Single	2 persons Double	2 persons Twin
Cascadian Hotel, 102 N. Wenatchee Ave.	$6.00-9.50	$9.00-12.50	$9.00-12.50
Avenue Motel, 720 N. Wenatchee Ave.	6.00-8.00	8.00-12.50	9.00-14.00
Rooney's Lodge, 821 N. Wenatchee Ave.	6.00	8.00	8.00-10.00
Apple Lane Motel, 906 N. Wenatchee Ave.	6.00	7.00	8.00
Lyle's Motel, 928 N. Wenatchee Ave	6.00	8.00	8.00-10.00

Gay's Motel, 1004 N. Wenatchee Ave.	5.00-6.50	6.50- 8.50	8.00-10.00
Chieftain Motel (pool), 1005 N. Wenatchee Ave.	6.00-7.50	8.50-10.00	9.00-12.00
Motel Lyon's (pool), 1836 N. Wenatchee Ave.	6.00-8.50	8.50- 9.00	8.00-11.00
Maple Leaf Motor Lodge, 1534 N. Wenatchee Ave.	5.00	7.50- 8.50	8.00-12.00
Starlite Motel, 1640 N. Wenatchee Ave.	6.00	7.00	10.00
Bel Air Motel, 1405 N. Wenatchee Ave.	6.00-7.50	8.00-10.00	8.50-10.00
Hanson's Lodge (pool), Sunnyslope Highway	6.00-7.50	8.00-10.00	8.50-12.00

Make reservations direct with the hotel or motel desired or with the Wenatchee Chamber of Commerce, P. O. Box 850, Wenatchee, Washington. Phone NOrmandy 2-2116. Include a minimum deposit of $5.00 with your request.

Write to the Washigton State Department of Commerce and Economic Development, General Administration Building, Olympia, Washington, for folder on Washington State Parks; Forest Camping in Washington; Washington State Map; Color Book of Washington State, Variety Vacationland.

Camping facilities are available at Squilchuck State Park, a 20 minute drive from the Columbia Hotel.

1961 COMMITTEE MEMBERSHIP POTATO ASSOCIATION OF AMERICA

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International Relations
To be appointed later.

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*Chairman

BOOK REVIEW

THE CHEMISTRY AND TECHNOLOGY OF EDIBLE OILS AND FATS: Proceedings of a Conference arranged by Unilever Limited at Research Department, Port Sunlight, March 10-12th. 1959. J. Devine and P. N. Williams, ed., Pergamon Press, New York, 1961, 154 pp., $6.00.

The proceedings involved seven papers entitled: Physical and Chemical properties of the constituents of edible oils and fats; The analysis of oils and fats; The determination of linoleic acid with special reference to isotopic dilution technique; Gas liquid chromatography and its application to the analysis of atheromatous plaques; Modern spectroscopic and X-ray techniques applied to oils and fats; and Fatty foods and the pattern of their consumption in the United Kingdom.

The book contains some very interesting tables showing per capita consumption of foodstuffs in the United Kingdom, particularly of edible oils and fats. There is also an excellent appendix entitled "Methods of Analysis", which gives the detailed proceedure of eleven most commonly used analyses of oils and fats.

This book is intended to give a bird's-eye view of the present state of knowledge on the nature and analysis of fats, the methods of industrial processing and the pattern of dietary fat consumption seen from the viewpoint of the economist. It is, therefore, an excellent book for medical and scientific personnel, who are engaged in the study of the chemistry and metabolism of lipids.

STEVEN S. CHANG
Department of Food Sciences
Rutgers, The State University

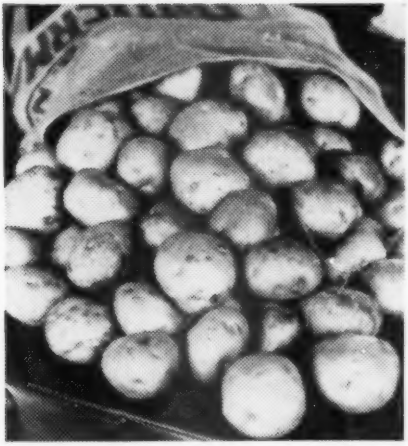
HEAVY LOADS OF SEBAGO POTATOES CAN BE SHIPPED SAFELY

Sebago potatoes shipped by rail from Florida in heavy loads—up to 50,000 pounds per car—reached their destination in good condition during shipping tests described in a report issued recently by the U. S. Department of Agriculture.

Shippers who use the heavy loads can reduce their freight cost per hundred-weight, the report states. Under an incentive tariff rate per car, adopted in 1957, the cost per cwt. decreases as size of load increases.

Scientists of USDA's Agricultural Marketing Service shipped three test cars of Sebago potatoes from Florida to Michigan and three others from Florida to Pennsylvania in April 1959. Loads in the six cars varied from 36,000 to 50,000 pounds of potatoes in 100-pound burlap bags. Results of the tests showed that bruising was slightly greater in loads of 50,000 pounds than in lighter loads, but not enough to offset the saving in freight charges for heavy loads under the per car rate.

A free copy of the report, "Effect of Heavy Loading on Quality of Sebago Potatoes Shipped from Florida by Rail," AMS-441, may be obtained from the Marketing Information Division, Agricultural Marketing Service, U. S. Department of Agriculture, Washington 25, D. C.



You get more No. 1's like these when you spray with Du Pont Manzate®

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One-chemical blight control—a spray program with "Manzate" maneb fungicide controls both early and late blights.

Better yields, quality and profits—"Manzate" helps boost yields as much as 40 bushels per acre . . . gives you more #1's, and naturally increases profits, as proved by growers in all major producing areas.

Safe to use—"Manzate" is tough on disease, mild on plants. It can be used on potatoes right up to harvest time . . . won't stunt plant growth.

Saves time and money—"Manzate" is a wettable powder, ready to mix wherever there's water. It is compatible with most insecticides and fertilizers so you save money with efficient combination sprays.

Saves trouble—"Manzate" has been thoroughly proved over the years—you *know* you can depend on it for top disease control, easy handling.

On all chemicals, follow labeling instructions and warnings carefully.

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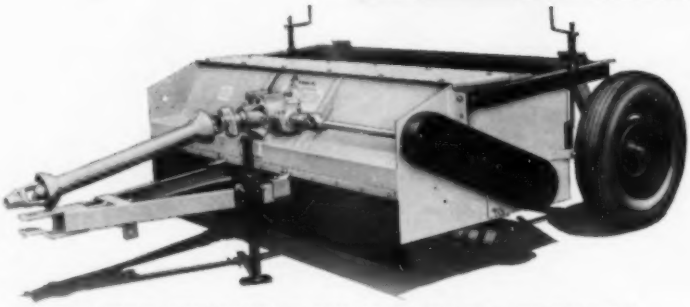
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

Loris Harmon,
Presque Isle, Maine,
potato grower says:

"MY SPEEDY POTATO VINE SHREDDER REALLY DID A CLEAN JOB — IN *ONE* TRIP THROUGH THE FIELD!"



SEE FOR YOURSELF WHY POTATO GROWERS NATIONWIDE ARE EXCITED ABOUT

THE SPEEDY VINE SHREDDER...

Yes, in potato growing areas, the Speedy Vine Shredder has been field proven under all possible conditions. Shreds vines with no vibrating or jumping . . . and does a superb job of cleaning the field. Because Speedy's knives or flails are of different lengths, they completely shred vines in the furrows as well as on the hills. Thus, even weedy vine-tangled fields are efficiently cleared. And economically done, too. The Speedy Vine Shredder pulls effortlessly under the toughest field conditions. It disintegrates all types of foliage . . . permitting faster, easier, harvesting.

The Speedy Potato Vine Shredder costs just $790.00 F.O.B. Oelwein, Iowa with steel knives . . . $840.00 with rubber flails. That's a saving of up to $300 compared to other vine beaters.

SEE A FREE DEMONSTRATION . . .
Your Speedy dealer will demonstrate the Speedy Vine Shredder right in your own field. To arrange a free demonstration, mail this coupon or see your Speedy dealer.

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☐ Gentlemen: Please arrange to give me your free, no-obligation demonstration in my field.

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INCREASE PROFITS — INCREASE QUALITY
of your
POTATO CROP

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TRI-BASIC COPPER SULFATE

Tri-Basic Copper Sulfate upgrades quality and yield—reduces Tuber Rot—Fewer Pick Outs—Better Shipping Quality—Higher Solids Content—Fewer Watery Potatoes—Better Chipping Stock—Increased Storage Life.

Micronized Tri-Basic Copper Sulfate is easy to apply in spray or dust form and it provides the nutritional element Copper so essential to healthy plant growth and increased yield.

Insure an increased yield of higher quality potatoes—Use Micronized Tri-Basic Copper Sulfate.

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GROWING ALFALFA SUCCESSFULLY

WHAT A new motion picture, "Growing Alfalfa Successfully," is now available for your showing. Produced by the American Potash Institute in close cooperation with official agricultural specialists, the new 16mm color movie is 25 minutes long and features special time-lapse photography to show how the plant grows and feeds. From the main movie, two 16mm shorts have been developed—"Alfalfa, Queen of the Forages" and "Good Alfalfa Requires Good Fertility"—which run 10 minutes each and contain the same information as the main movie in two different condensed versions.

HOW Any one of the three movies can be booked free of charge by contacting Department BC, American Potash Institute, 1102 16th St., N. W., Washington 6, D. C., giving a date and alternate desired for showing, as well as name and organization represented.

ANOTHER SERVICE OF

AMERICAN POTASH INSTITUTE, INC.

SERVING AGRICULTURE FOR OVER TWO DECADES

1102 Sixteenth St., N. W. Washington 6, D. C.

Member Companies: American Potash & Chemical Corporation • Duval Sulphur & Potash Company • Potash Company of America • Southwest Potash Corporation • United States Borax & Chemical Corporation

A craftsman who is well experienced in the production of POTATO-CHIPS is desired in the position of **technical chief** of an European factory. Besides potato-chips the production of some other refined goods may be taken into consideration. We wish the applications to be sent to us for further negotiations through this paper with the signature "Potato-chips."

Colorado Potato Beetle *Leafhoppers* *Fleabeetles* *Potato Tuberworms*
Armyworm *Green Stink Bug* *Leaf-footed plant bug* *Tough-to-kill aphids*

Thiodan®

kills them all: keeps killing them

Besides positive control of all these pests, Thiodan provides every other feature you've looked for in a new, broad spectrum insecticide. It provides really long-lasting residual control and it's safer to use than many pesticides. Thiodan is harmless to vines and causes no off-flavor in potatoes. And what may be a bigger bonus – recent field experience indicates that Thiodan treated plots produced greater yields than other standard treatments under controlled test conditions.

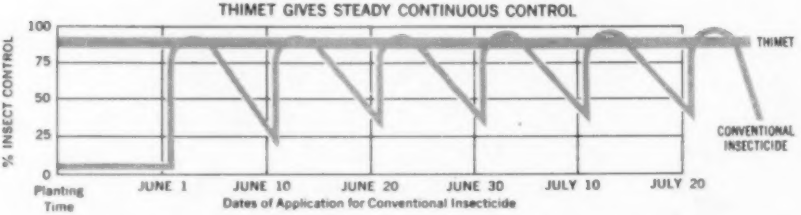
On all counts, performance, residual control and safety, only Thiodan provides so much help producing bigger, better crops. See your dealer today!

Thiodan®

TECHNICAL CHEMICALS DEPT. • NIAGARA CHEMICAL DIVISION,
FOOD MACHINERY AND CHEMICAL CORPORATION • MIDDLEPORT, N. Y.

TAKE THE UPS AND DOWNS OUT OF POTATO INSECT CONTROL

One application of Thimet® insecticide at planting time gives potatoes season-long protection, prevents reinfestations, eliminates the need for timed applications.



Thimet gives potatoes protection that starts at a high level and *stays* at a high level. Reason: Thimet is a powerful *systemic* insecticide. It actually enters and spreads through the entire plant, where it is protected from weathering . . . and where it can *protect* the entire plant. No matter where insects attack, your potatoes are protected. *And, Thimet lets you take care of practically all your insect control at planting time.*

Compare Thimet with the insecticides you've *been* using. Their effectiveness is highest right after application. Then weathering rapidly cuts their effectiveness. It takes another . . . and another . . . application to re-establish control. Thimet saves the expense of field checking and repeated applications, gives you full protection against insect build-ups, because there are no weak spots in a Thimet control program.

How to use Thimet...what it does

Thimet Insecticide comes in granular form. You apply it in bands along the row, or in the furrow at planting time. As your potatoes start to grow, their roots pick up Thimet. It travels all through the plants, makes every stem and leaf deadly to insects.

In most cases, Thimet gives steady, high-level control through the season. In some areas where heavy, late-season build-ups of insects occur, *supplementary* use of a conventional insecticide may be necessary. In many major potato areas, Thimet gives season-long control of aphids, leafhoppers, leafminers, and psyllids and reduces flea beetle infestations. Thimet is easily applied by a granular applicator that attaches to the planting rig. This unit will accurately apply the material at planting time.

Write for leaflet PE 5095. American Cyanamid Company, Agricultural Division, New York 20, N. Y. ®*THIMET is American Cyanamid Company's trademark for phorate.*

The label instructions on Cyanamid products, and on products containing Cyanamid ingredients, are the result of years of research and have been accepted by Federal and/or State Governments. Always read the labels and carefully follow directions for use.

CYANAMID

THIMET

SYSTEMIC INSECTICIDE

CYANAMID SERVES THE MAN WHO MAKES A BUSINESS OF AGRICULTURE